2017-04-12

Innovative Experimentation Enables Effective Employment of Unmanned Systems [video]

Sanchez, Susan

INNOVATIVE EXPERIMENTATION enables effective employment of unmanned systems

Susan M. Sanchez and Thomas W. Lucas

SEED Center for Data Farming
Operations Research Department
Naval Postgraduate School

Data Mining vs. Data Farming

- Miners seek valuable buried nuggets
  - Miners have no control over what's there or how hard it is to separate it out
  - Data Mining seeks valuable information buried within massive amounts of data
- Farmers cultivate to maximize yield
  - Farmers manipulate the environment to their advantage: pest control, irrigation, fertilizer, etc.
  - Data Farming manipulates simulation models to advantage with designed experimentation

Bottom Line Up Front

- Complex, high-dimensional models underpin many important decisions in DoD and beyond.
  - Computational models of physical systems
  - Simulation models of military operations
- Recent breakthroughs enable researchers to gain much more information from these models…this is what SEED is all about!
  - New data farming applications: applied research (student theses)
  - New data farming methods
  - Data farming workshops / educational outreach

Recent and current theses exploring unmanned systems

- LT John Tanalega, U.S. Navy (March 2018), Distributed lethality, possibly exploring adaptive force packages with and without a medium displacement unmanned surface vehicle (MDUSV)
- CPT Elle Ekman, U.S. Marine Corps (June 2017), Simulating sustainment for an unmanned logistic system concept of operation in support of distributed operations
- LCDR Kevin Solem, U.S. Navy (March 2017), Quantifying the potential benefits of anti-submarine warfare (ASW) continuous trail unmanned vessels (ACTUV) in a tactical ASW scenario (UNCLAS/Restricted distribution)
- CPT Sangbum Kim, Republic of Korea Army (March 17), Feasibility analysis of UAV technology to improve tactical surveillance in South Korea's rear area operations

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TechCon: overview
on Tuesday 11 April
by CPT Ekman

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TechCon: overview on Tuesday 11 April by Prof. Jeff Kline

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- LT Michael Schambach, U.S. Navy (September 2016), Analysis of a long-range undersea strike weapon (UNCLAS/Restricted distribution)
- CDR Melvin Cheang, Singapore Navy (Sep 2016), Operational Energy Capability Portfolio for Protection of Maritime Forces against Small Boat Swarms
- CDR Kevin Williams, U.S. Navy (Sep 2016), Exploring Options for Adding a Magnetic Anomaly Detection (MAD) Capability to the P-8A
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- LT John Burns, U.S. Navy (Sep 2015), "Validating a TACMEMO Using Massive Agent-Based Simulation" (RESTRICTED)

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CRUSER presentation, January 2017

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Operational Energy Capability Portfolio for Protection of Maritime Forces against Small Boat Swarms

NAVAL POSTGRADUATE SCHOOL

Simulation Experiments & Efficient Designs Center for Data Farming
Naval Postgraduate School
http://harvest.nps.edu

Researchers:

– CDR Mevin Cheang, Singapore Navy

Background:

The small boat swarm is a likely asymmetric threat to naval conventional warfare missions. An operational energy (OE) efficient capability portfolio is needed to ensure operational reach and endurance.

Research questions:

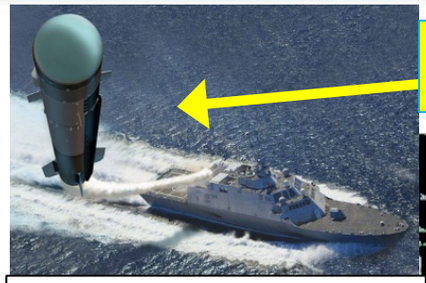
- How effective is force protection, so the naval force can continue on its primary mission?
- How do OE consideration constrain the naval forces' options?
- What operational and doctrinal mitigation policies can be applied?
- What are cost-effective options for defending against this threat?

Approach:

- Create a simulation in MANA (agent-based modeling platform)
- Use a designed experiment to investigate various scenarios, based on the critical operational issues and research questions
- Assess different capability portfolio options

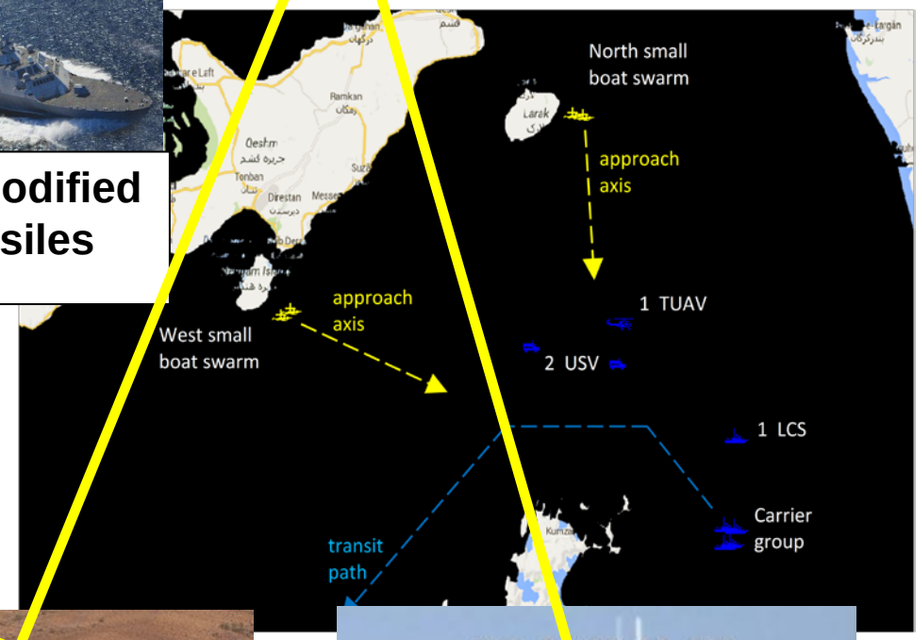
Findings:

- Efficient mixes of LCS, USVs, and TUAVs are critical



LCS with modified Hellfire missiles
(from Eshel 2015)

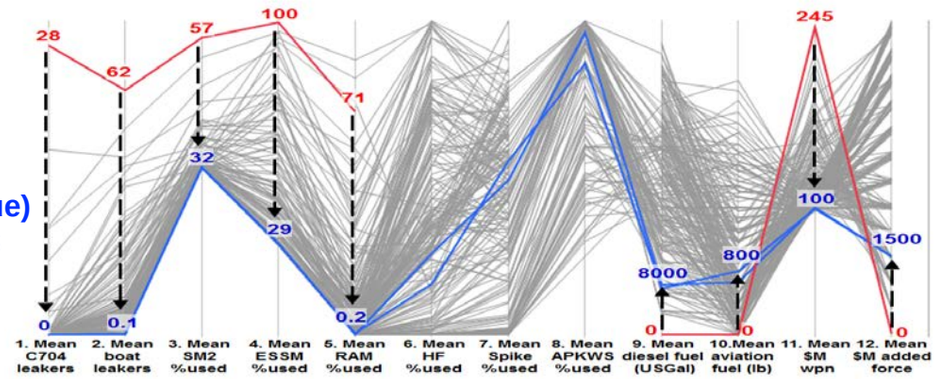
Assets in portfolio



Firescout MQ-8B TUAV
(from Osborn 2013)

Autonomous 11m USV with Spike LR missile
(from Defense-Aerospace 2012)

Baseline (red) results in more leakers, higher weapons $ than **alternatives (blue) involving 3 LCS with 5-6 TUAVs**



Analysis of a long-range undersea strike weapon

NAVAL POSTGRADUATE SCHOOL

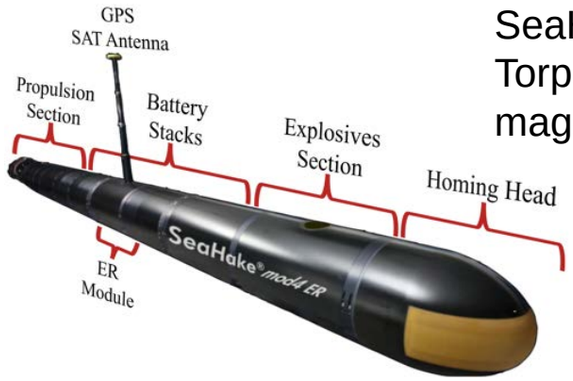
Simulation Experiments & Efficient Designs
Center for Data Farming
Naval Postgraduate School
http://harvest.nps.edu

Researchers:

– LT Michael Schambach, USN

Background:

The German torpedo SeaHake mod4 ER has a maximum range of over 75 nautical miles. Understanding how to employ this type of weapon will be beneficial to the U.S. Navy.



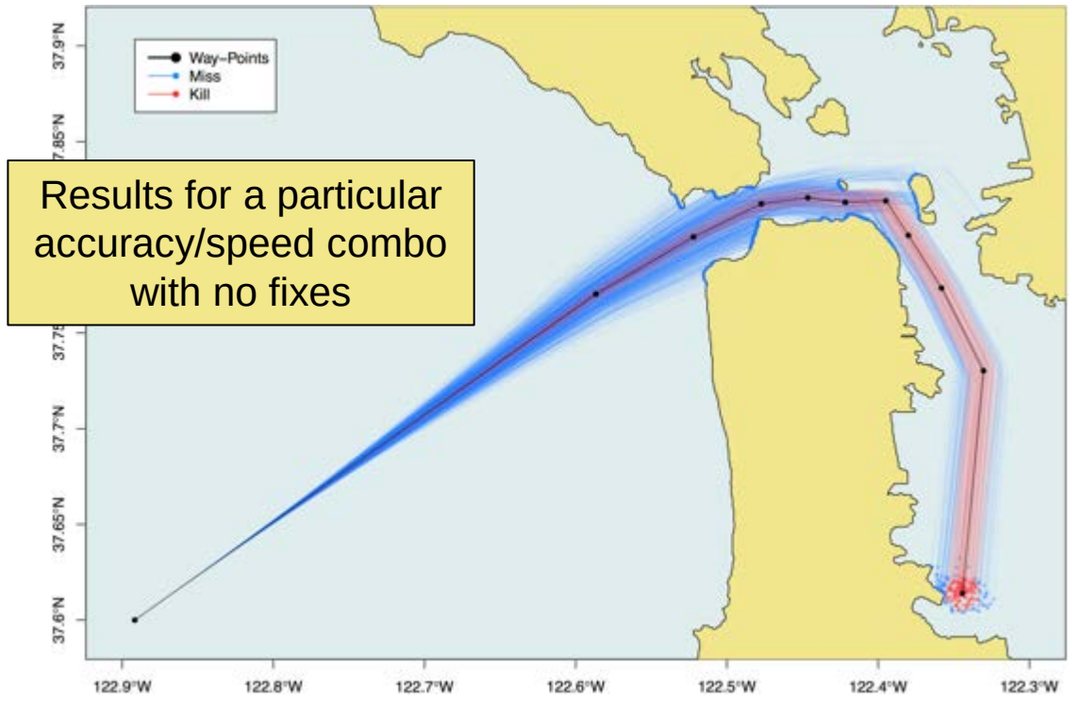
SeaHake Mod4 ER Torpedo (*Naval Forces* magazine, 2014)

Research questions:

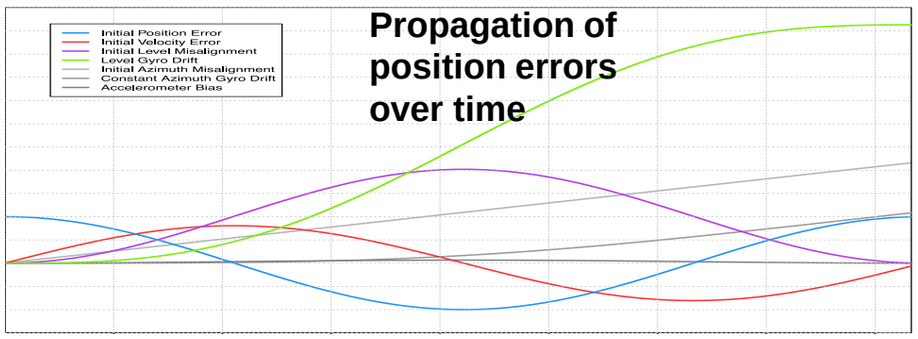
- How can we balance navigation accuracy and detectability to maximize the probability that the long-range torpedo reaches its destination?

Approach:

- Create a time-step simulation in R to specify the dynamics as the torpedo travels to its target.
- Incorporate three levels of inertial navigation system (INS): low, medium, and high accuracy
- Simulate large numbers of torpedoes, while varying INS and other errors, to assess the kill probability under various conditions
- Explore how the number and location of GPS fixes should change if shore-based radar locations are known



Results for a particular accuracy/speed combo with no fixes



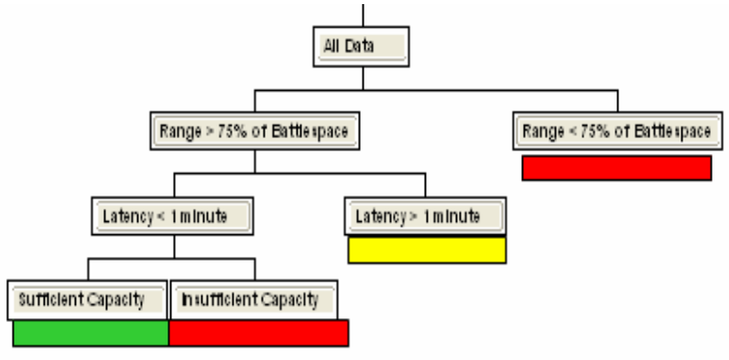
Findings:

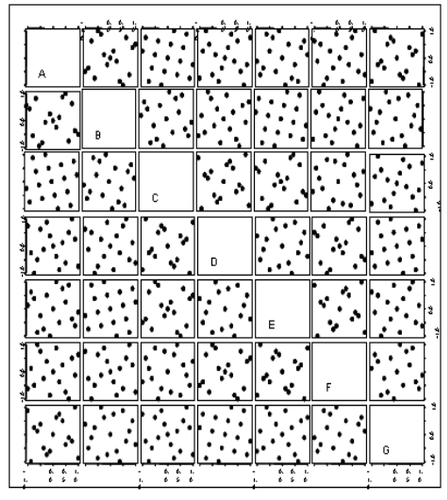
- A robust algorithm calculates the minimum number of fixes, and their locations, unique to the specific scenario modeled.
- Visual interface useful for modifying scenarios, presenting results
- Simulation framework could be applied to other weapon systems, unmanned underwater vehicles (UUVs), and autonomous UVs

Overview: The SEED Center

- **SEED: Simulation Experiments & Efficient Designs**
- **Specialize in new methods for exploring high-dimensional simulation models**
- **Enabling technologies**
  - New design of experiments
  - High-performance computing
  - Computational models
  - Data mining and visualization
- **Revolution in analysis capabilities**
  - Quick turnaround
  - Variety of broad insights
  - Address uncertainties
  - Robust solutions


Computational Models





SEED Center Mission:
Make modeling & simulation more effective for decision makers

Large-scale computational experiments are transformative

"Petaflop machines like Roadrunner have the potential to fundamentally alter science and engineering…[allowing scientists to] perform experiments that would previously have been impractical."

The New York Times, June 9, 2008

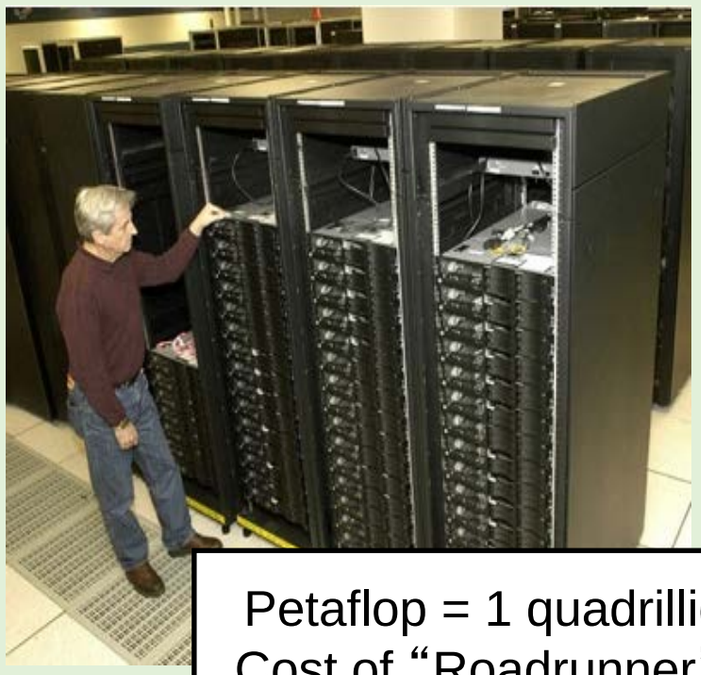
Experimentation is hard: "2^{100} is forever"

—Maj Gen Jasper Welch

Even with today's most powerful computers, brute force exploration of 100 variables at 2 levels for a simulation that runs in one second would take many times the age of the universe…so we need to be smart!

Moore's Law is not enough!

The "curse of dimensionality" cannot be solved by hardware alone.

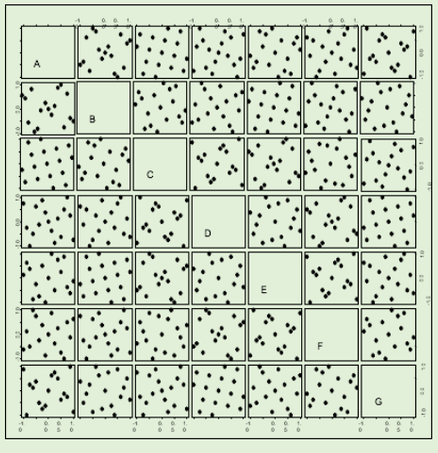


Petaflop = 1 quadrillion ops/second
Cost of "Roadrunner"= $133 million

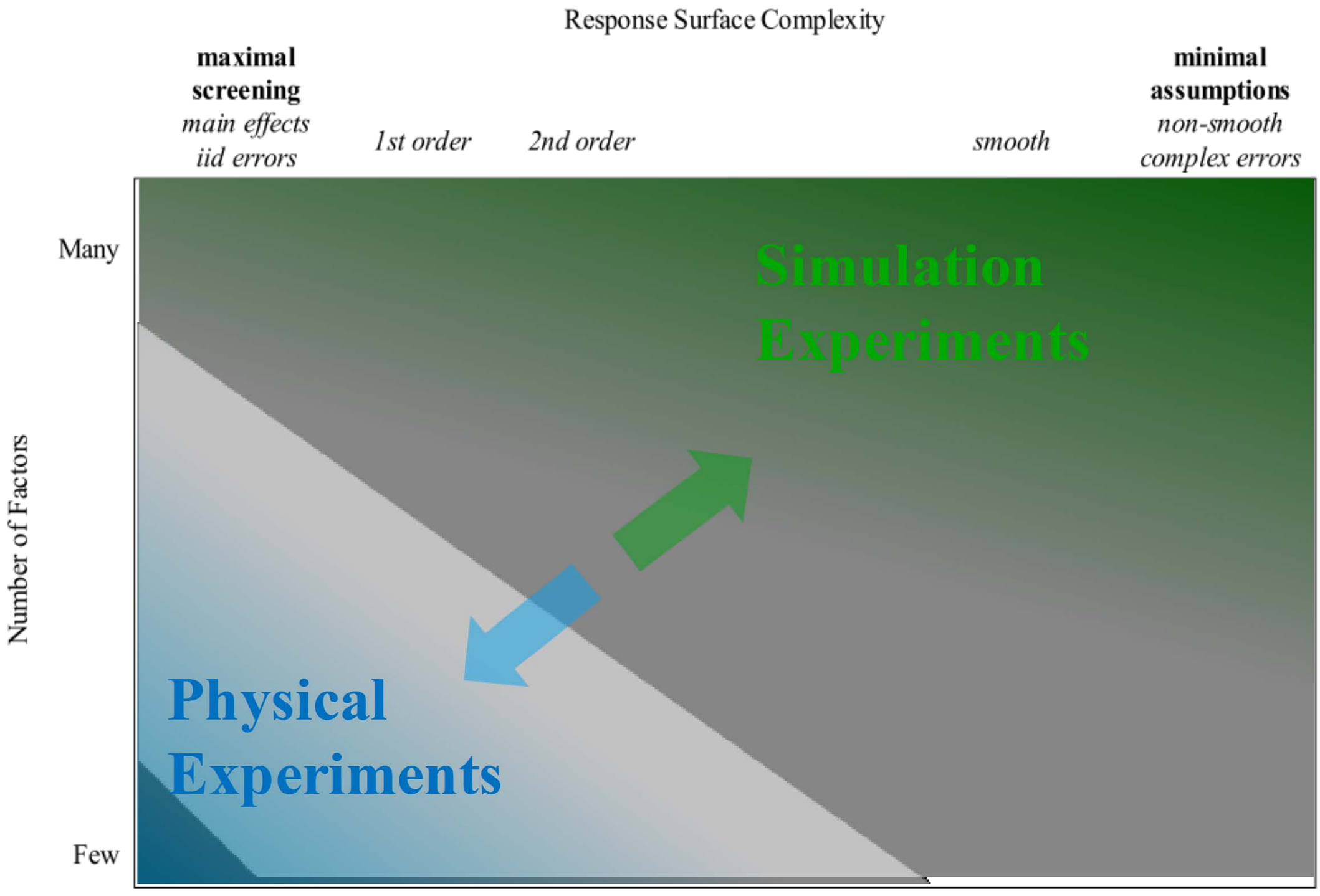
SEED Center is overcoming the curse of dimensionality…

With large-scale efficient experimental designs, we generate "better big data" and regularly study hundreds of factors for longer-running simulations in hours, days, or weeks on high-performance computing clusters…

Simulation Experiments & Efficient Designs
Center for Data Farming
Naval Postgraduate School



Simulation is different…



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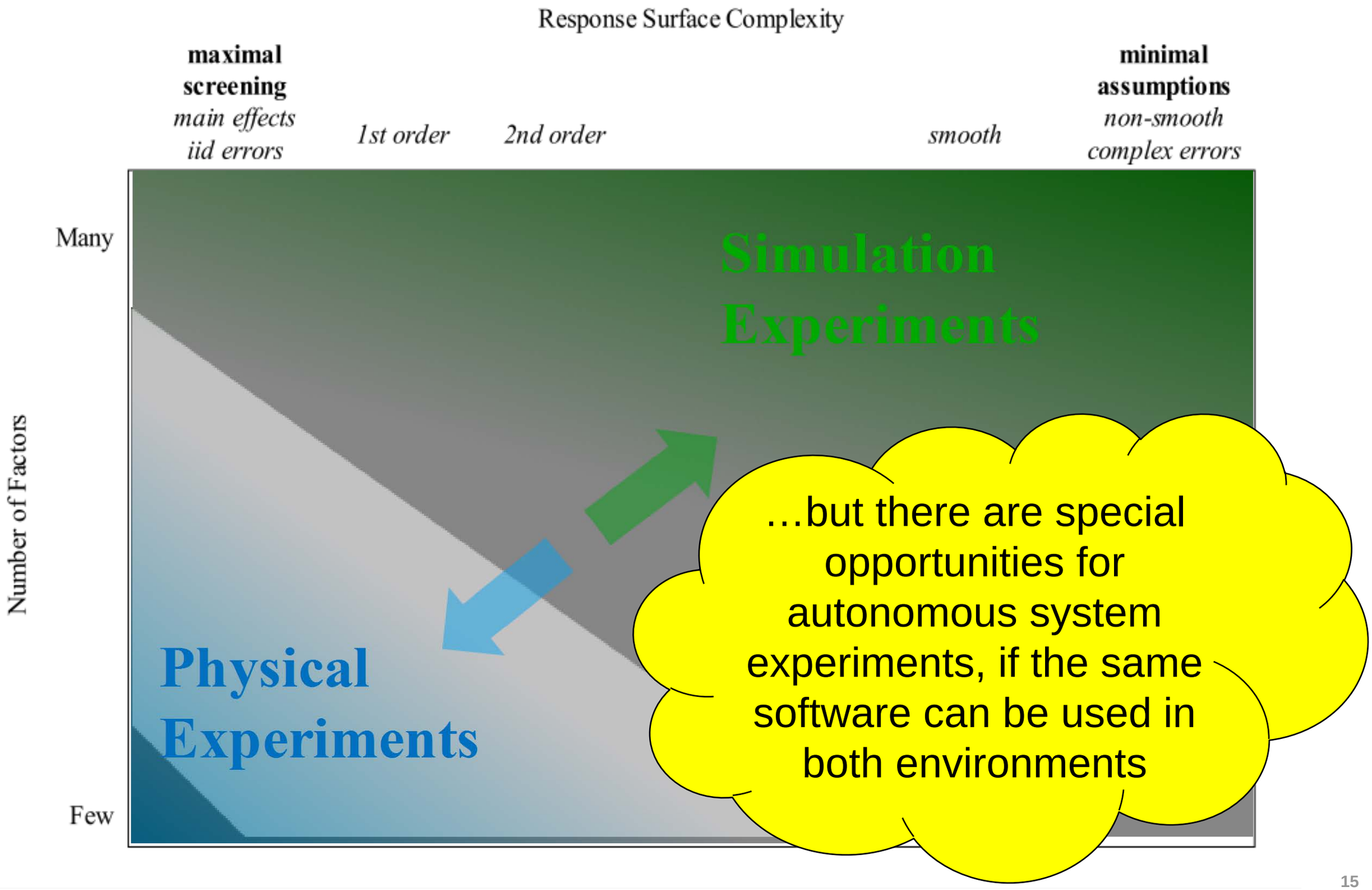
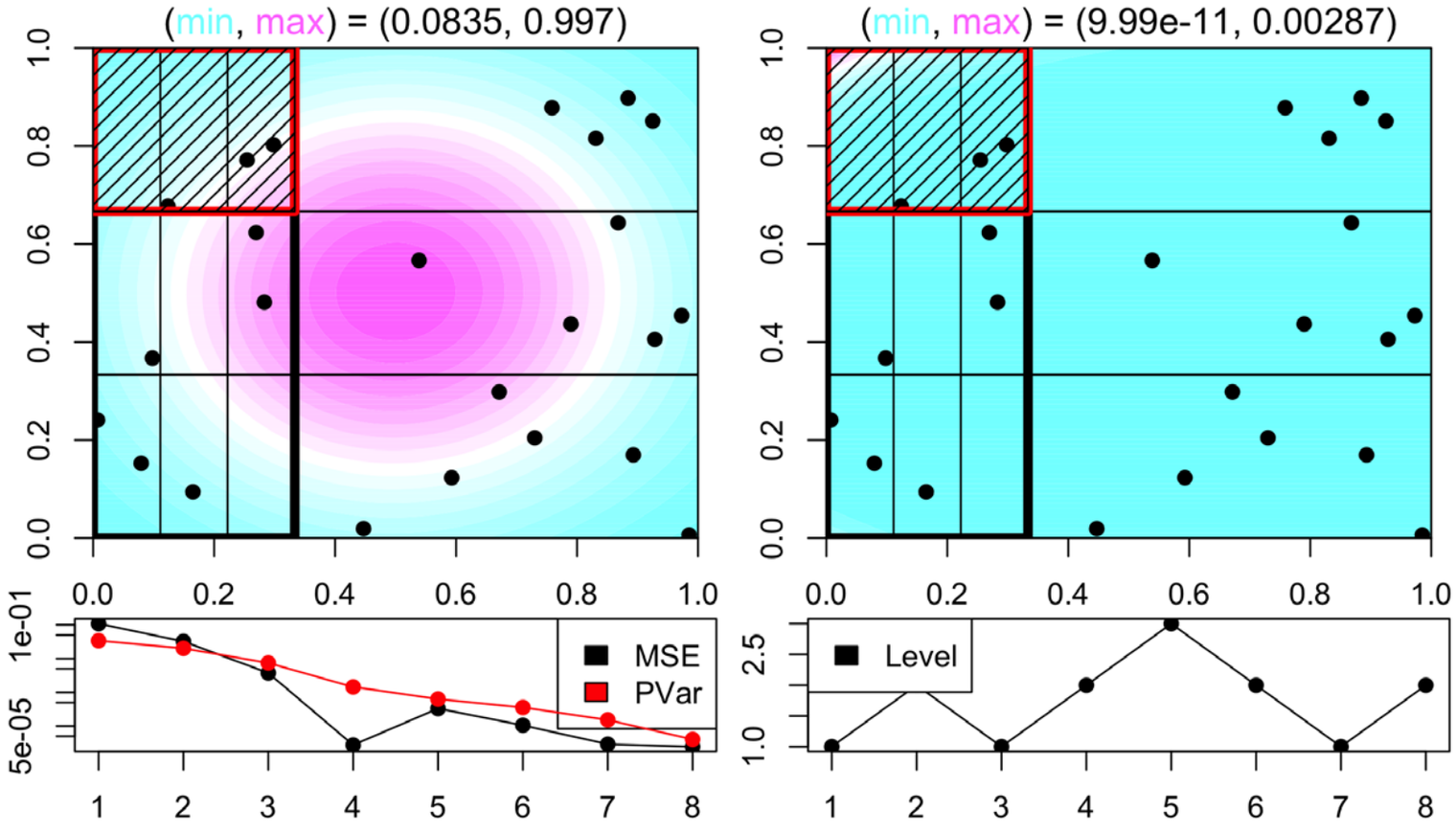


New methods for design

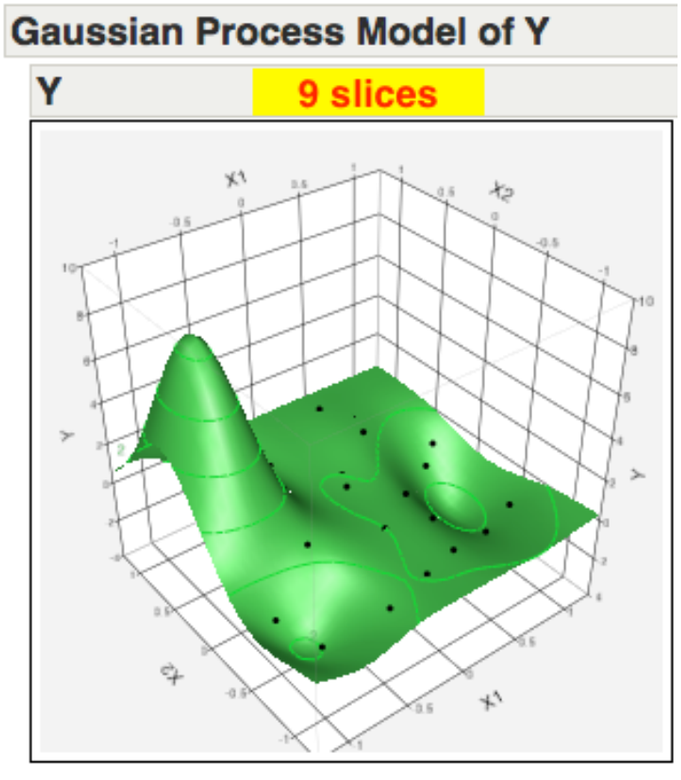
- Adaptive sFFLHD designs: sequential sampling that takes data in “slices” to achieve good design characteristics (space-filling, orthogonality) at various levels – but allow for the simulation experiments to focus first on interesting regions.
  - Goal: get “smart” simulation data on an ongoing basis, vs. one snapshot
  - Work in process (Prof. Susan Sanchez with NREIP Intern/NWU PhD student Collin Erikson, NWU Prof. Bruce Ankenman)

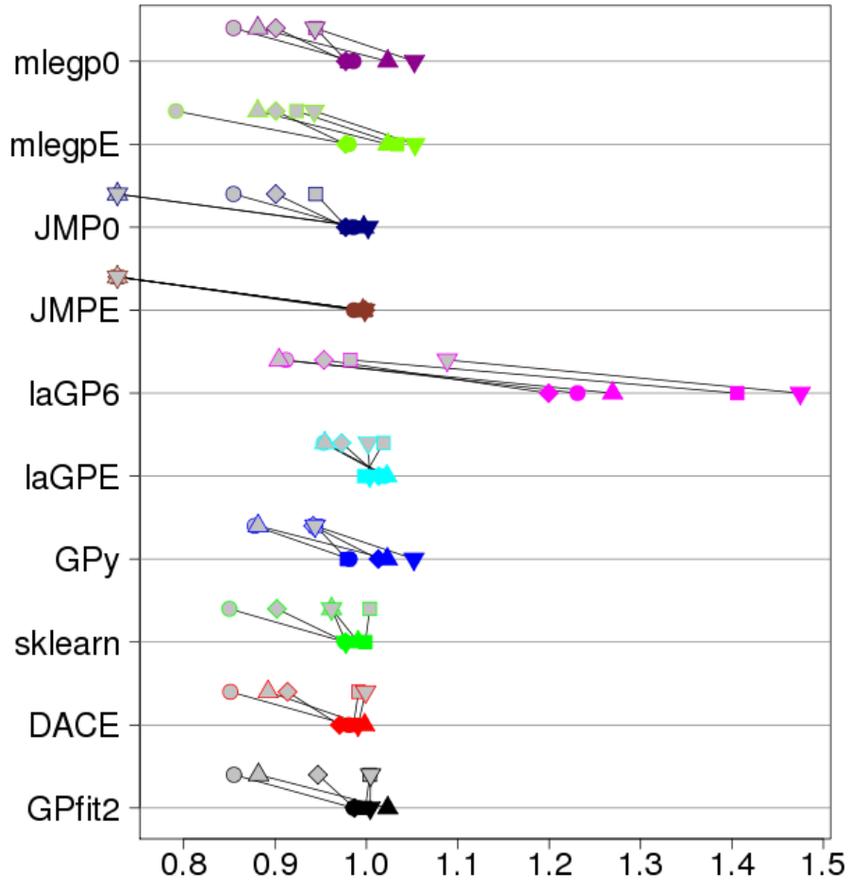


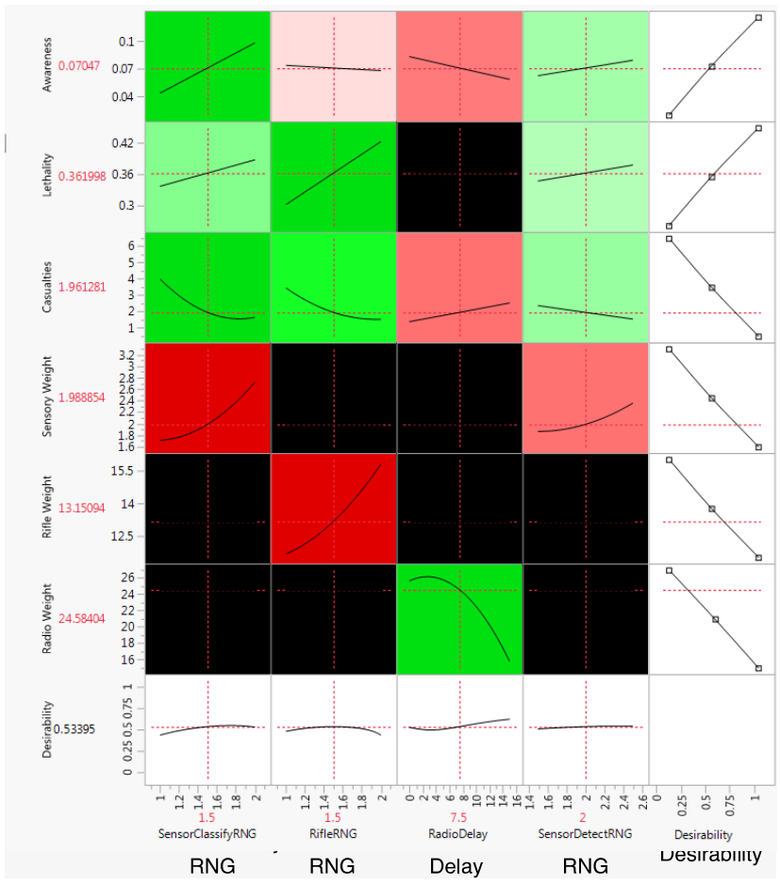
New methods for analysis

Goal: better understanding of a different class of flexible metamodels (surrogate models of I/O for simulation, as functions of factors)

- Working paper: C. Erickson, B. E. Ankenman, S. M. Sanchez, “Comparison of Gaussian process modeling software” (extended abstract published in WSC ‘16 Proceedings, full paper under 2nd review)
- Investigating GP metamodels for use in tradespace analysis, adaptive sequential design procedures







Data Farming Workshops / Educational Outreach*

Completed…

- ½ day tutorial as part of OCEANS ‘16 in Monterey, CA
  http://www.oceans16mtsieeemonterey.org/
  Data Farming 101 (Monday morning 19 Sep 2016)

- ½ day tutorial as part of WSC ’16 in Washington, D.C.
  http://www.wintersim.org
  Data Farming 101 (Sunday 11 Dec 2016)

- Full day tutorial as part of Science of Test Workshop in Springfield, VA
  Data Farming 101 (Monday 3 April 2017)

- One week tutorial at Defence Science & Technology group in Melbourne, Australia (May 2016)

** Some funded by CRUSER, some by others*

Data Farming Workshops / Educational Outreach

Upcoming…

- ½ day tutorial as part of WSC ’17 in Las Vegas, NV
  http://www.wintersim.org
  Data Farming 101 (Sunday 3 Dec 2017)

- Initial discussion / resources about data farming for
  YOUR MODEL (ongoing)

“Petaflop machines like Roadrunner have the potential to fundamentally alter science and engineering…[allowing scientists to] perform experiments that would previously have been impractical.” *The New York Times, June 9, 2008*

Designed experiments yield “better data, not just big data”

questions?

http://harvest.nps.edu